Free Executive Summary

Evaluation of Demonstration Test Results of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: A Supplemental Review for Demonstration II

Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: Phase II, Board on Army Science and Technology,National Research Council

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Executive Summary

By direction of Congress, the U.S. Department of Defense's (DoD's) program manager for the Assembled Chemical Weapons Assessment (PMACWA) asked the National Research Council (NRC) Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: Phase II (the ACW II committee) to conduct an independent scientific and technical assessment of three alternative technologies (referred to as Demo II) under consideration for the destruction of assembled chemical weapons at U.S. chemical weapons storage sites. The three technologies are AEA Technologies Corporation's (AEA's) electrochemical oxidation process; the transpiring-wall supercritical water oxidation and gas-phase chemical reduction processes of Foster Wheeler/Eco Logic/Kvaerner (FW/EL/K); and Teledyne-Commodore's solvated electron process. Each of these technologies represents an alternative to incineration for the complete destruction of chemical agents and associated energetic materials. The demonstration tests were approved by the PMACWA after an initial assessment of each technology. The results of that initial assessment were reviewed by an earlier NRC committee, the Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons (the ACW I committee) (NRC, 1999).

For the present review, the committee conducted an indepth examination of each technology provider's data, analyses, and demonstration test results for the critical components tested. This review report supplements the ACW I report and considers the demonstration performance of the Demo II candidate technologies and their readiness for advancement to pilot-scale implementation. Because testing in these areas is ongoing, the committee decided to cut short its fact-finding efforts for input to this report as of March 30, 2001. This cutoff was necessary in order to provide the sponsor with the needed information in a timely fashion.

In 1996 the U.S. Congress enacted two laws, Public Law 104-201 (authorization legislation) and Public Law 104-208 (appropriation legislation), mandating that DoD assess alternative technologies to the baseline incineration process for the demilitarization of assembled chemical munitions. In December 1996 the deputy to the commander of the Soldier Biological Chemical Command was appointed as the PMACWA. Subsequently, seven technologies designed for the complete destruction of assembled chemical weapons were evaluated (ACW I report), and on July 29, 1998, three of them were selected for the Demonstration I (Demo I) phase of the ACWA program.

The PMACWA requested that the NRC perform an independent evaluation of the seven technology packages that had been selected originally during earlier phases of the Assembled Chemical Weapons Assessment (ACWA) program and deliver a report by September 1, 1999. However, to meet that deadline, the NRC ACW I committee had to terminate its data-gathering activities on March 15, 1999, before the demonstration tests had been completed (NRC, 1999).

In September 1999, the PMACWA asked the ACW I committee to examine the results of tests demonstrating the operations of three of the original seven alternative technologies and to determine if they had changed the committee's original findings, recommendations, and comments. Accordingly, the NRC published a supplemental report in March 2000 (NRC, 2000), at which time the ACW I committee was disbanded.

In 1999, Congress passed Public Law 105-261, mandating as follows:

> The program manager for the Assembled Chemical Weapons Assessment shall continue to manage the development and testing (including demonstration and pilot-scale testing) of technologies for the destruction of lethal chemical munitions that are potential or demonstrated alternatives to the baseline incineration program. In performing such management, the program manager shall act independently of the program manager for Chemical Demilitarization and shall report to the Under Secretary of Defense for Acquisition and Technology.

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The Army was also directed to continue its coordination with the NRC.

Congress extended the PMACWA's task through Public Law 106-79 by mandating that he "conduct evaluations of [the] three additional alternative technologies under the ACWA program, . . . proceed under the same guidelines as contained in Public Law 104-208 and continue to use the Dialogue process and Citizens' Advisory Technical Team and their consultants." In response, the PMACWA initiated a new test program, commonly referred to as Demo II, to investigate whether three of the alternative technologies remaining from the original testing were ready to proceed to an engineering design phase.[1] The remaining technologies were from AEA, FW/EL/K, and Teledyne-Commodore. The seventh of the original technologies had been judged to be too immature for further testing during the original multitiered selection process.

In response to Congress, a second NRC committee, the Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: Phase II (ACW II committee), was formed and tasked to produce three reports: (1) an evaluation of the Demo II tests (Task 1), (2) an evaluation of two engineering design studies (EDSs) and tests for use at the Pueblo, Colorado, storage site (Task 2), and (3) an evaluation of EDS packages and tests for the Blue Grass, Kentucky, site (Task 3).

The statement of task for Task 1 is as follows:

> At the request of the DoD's Program Manager for Assembled Chemical Weapons Assessment (PMACWA), the NRC Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons will provide independent scientific and technical assessment of the Assembled Chemical Weapons Assessment (ACWA) program. This effort will be divided into three tasks. In each case, the NRC was asked to perform a technical assessment that did not include programmatic (cost and schedule) considerations.
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> Task 1
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> To accomplish the first task, the NRC will review and evaluate the results of demonstrations for three alternative technologies for destruction of assembled chemical weapons located at U.S. chemical weapons storage sites. The alternative technologies to undergo demonstration testing are: the AEA Technologies electrochemical oxidation technology, the Teledyne Commodore solvated electron technology, and the Foster Wheeler and Eco Logic transpiring wall supercritical water oxidation and gas phase chemical reduction technology. The demonstrations will be performed in the June through September 2000 timeframe. Based on receipt of the appropriate information, including: (a) the PMACWA-approved Demonstration Study Plans, (b) the demonstration test reports produced by the ACWA technology providers and the associated required responses of the providers to questions from the PMACWA, and (c) the PMACWA's demonstration testing results database, the committee will:
>
> - Perform an in-depth review of the data, analyses, and results of the unit operation demonstration tests contained in the above and update as necessary the 1999 NRC report, Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons (the ACW report).
> - Determine if any of the AEA Technologies, Teledyne Commodore, and Foster Wheeler/Eco Logic technologies have reached a technology readiness level sufficient to proceed with implementation of a pilot-scale program.
> - Produce a report for delivery to the PMACWA by July 2001 provided the demonstration test reports are made available by November 2000. (An NRC report delivered in March 2000 covered the initial three technologies selected for demonstration phase testing.)

In this current supplemental review, which responds to Task 1, the ACW II committee provides an extensive review of the data, analyses, and demonstration test results for critical components of the demilitarization processes of AEA, FW/EL/K, and Teledyne-Commodore. Like the first supplemental review (NRC, 2000), this review evaluates the effects of the new test results on the findings and recommendations in the original ACW I committee report (NRC, 1999) and assesses the level of maturity attained by each technology for proceeding to the engineering design phase of development. A separate chapter is devoted to each technology, and the chapters are organized as follows: descriptions of the demonstrated unit operations; descriptions of the tests used in the study, including committee commentary; a discussion of the effects of the demonstration results on previous findings; and, finally, new findings derived from this supplemental review. Chapter 5 considers the earlier general findings and recommendations and presents new ones in light of the demonstration test results.

In general, very few of the original findings and recommendations were changed as a result of the new tests. In some cases, the original findings and recommendations were confirmed. The new findings and recommendations are presented below by technology. The level of development of unit operation processes from the candidate technologies is summarized in Table ES-1. General findings and recommendations are also presented below.

[1] The AEA, Eco Logic, and General Atomics technology packages were chosen by the PMACWA to undergo engineering design studies for the destruction of the assembled chemical weapons at the Blue Grass Army depot. This decision was made by the PMACWA prior to the issuance of this NRC report.

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TABLE ES-1 Summary Evaluation of the Maturity of Demo II Unit Operations and Processes

Technology Provider/Unit Operation or Process	Hydrolysates			Agent Munitions			
	VX/GB	HD	Energetics	VX/GB	HD	Energetics	Other
AEA							
SILVER II™[a]				C	C	C	
Solid/liquid waste treatment				C	C	C	
Gaseous waste treatment				D	D	D	
Foster Wheeler/Eco Logic/Kvaerner							
TW-SCWO	B	B	C				
GPCR™				B	B	B	B[b,c]
Teledyne-Commodore							
Ammonia fluid jet cutting and washout system				D	D	E	
SET™				D	D	D	C[b]
Persulfate oxidation (agent)				D	D	D	
Peroxide oxidation (energetics)				D	D	D	
Metals parts and dunnage shredding							A[b,c]

NOTE: Environmental and safety issues were considered in assigning maturity categorizations. Schedule and cost issues were not considered. The letter designations are defined as follows (a blank space indicates that categorization was not applicable for that material): A, demonstration provides sufficient information to justify moving forward to full-scale design with reasonable probability of success; B, demonstration provides sufficient information to justify moving forward to the pilot stage with reasonable probability of success; C, demonstration indicates that unit operation or process requires additional refinement and additional demonstration before moving forward to pilot stage; D, not demonstrated, and more R&D is required; and E, demonstrated unit operation or process is inappropriate for treatment.

[a]Includes integrated gas polishing system to support demonstration.

[b]Dunnage.

[c]Metal parts.

SUPPLEMENTAL FINDINGS AND RECOMMENDATIONS

AEA Demonstration Test

Finding DII AEA-1. The overall process flow has been further complicated by major design changes in response to the Demo II testing. These changes include the addition of the impurities removal system (IRS), catalytic oxidation (CATOX) units, and a flow return circuit from the catholyte to the anolyte circuit. All three changes require small-scale and pilot-scale testing. Such modifications further complicate the interfaces between process units, which increases the time required for development, start-up, and commissioning of the full-scale system. Integration of the operating units will make achievement of a viable total solution very difficult.

Finding DII AEA-2. The discovery of organic material migration across the electrochemical cell membrane will require major modifications in design and operation, such as recycling of the catholyte material to the anolyte circuit and the addition of hydrocyclones in the catholyte circuit.

Finding DII AEA-3. The formation of intermediate oxidation by-products raises operational issues, including slower processing rates and reduced electrochemical efficiency. During the testing with tetrytol in the 12 kW unit, the problems were severe enough to cause the runs to be extended well beyond the planned processing times.

Finding DII AEA-4. The generation of new energetic compounds trinitrobenzoic acid, picric acid, and trinitrobenzene (TNBA, PA, and TNB) in the course of processing increases the complexity and hazards of the SILVER II™ process. Although the explosion hazard is reduced as the energetic feed is consumed, it is not completely eliminated until all energetic intermediates are destroyed.

Finding DII AEA-5. During the treatment of M28 in the Demo II test, lead oxide and other materials accumulated on cell anodes. The committee believes that a maintenance procedure for routine cleaning of the anodes will be required.

Finding DII AEA-6. Low steady-state electrochemical efficiencies (20 to 30 percent) were observed during treatment

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of tetrytol. These low efficiencies will decrease the throughput per cell and increase processing time and energy consumption.

Finding DII AEA-7. Volatile organic compounds (VOCs) were detected in the off-gas of the AEA process technology. AEA has now included a CATOX unit in the preliminary design. The committee believes that the introduction of this additional unit operation will further complicate the scale-up and integration.

Finding DII AEA-8. The IRS for removing salts (sulfates, phosphates, silver fluoride), excess water, and any metals that may be present requires extensive development and integration. The IRS has not yet been described in sufficient detail to allow for a meaningful assessment.

Recommendation DII AEA-1. The possible formation of lead picrate when mixed energetic feeds are treated must be investigated before any processing of lead-containing propellant, TNT-based energetics, or tetryl is undertaken.

Recommendation DII AEA-2. The IRS, the CATOX units, the return flow, and all other major modifications to the system must be tested and proven during the EDS design phase.

Recommendation DII AEA-3. AEA must validate complete destruction of all energetic intermediates during the EDS design phase.

Recommendation DII AEA-4. AEA must conduct additional tests to identify suitable materials of construction to overcome corrosion problems encountered owing to the formation of hydrofluoric acid (HF) in the treatment of GB.

Foster Wheeler/Eco Logic/Kvaerner Demonstration Tests

Finding DII FEK-1. The proposed full-scale TW-SCWO system has design and operating conditions significantly different from those tested in Demo II. These include the temperature of the transpiration water at the inlet; pH of the feed; turbulence in the reactor; and use of pure oxygen, not air, as the oxidant.

Finding DII FEK-2. The proposed full-scale design for the TW-SCWO system involves a scale-up in reactor cross-sectional area by a factor of 2 from the Demo II test unit and an increase in reactor throughput by a factor of 35. Performance under these full-scale design conditions has not been demonstrated.

Finding DII FEK-3. Aluminum present in the hydrolysates, which could lead to the formation of slurries and plugging, could be a problem. The proposed changes for mitigating this problem (e.g., changing operating conditions and/or removing aluminum during weapon disassembly) must be tested.

Finding DII FEK-4. Demo II tests confirmed that firing tubes and other solids could be treated to a 5X condition by the GPCR™ process.

Finding DII FEK-5. All waste streams have been or can be characterized sufficiently for engineering design to proceed.

Finding DII FEK-6. The current sampling and monitoring systems for agent in gaseous streams have not been certified or validated for use with the GPCR™ process off-gas.

Finding DII FEK-7. The product gas from the GPCR™ process does not meet the EPA syngas requirements because of high benzene and polyaromatic hydrocarbon content.

Finding DII FEK-8. While no agent was detected in the scrubbing solutions and scrubber filters, the ability of the GPCR™ process to destroy HD in mortars and neat GB could not be confirmed because sampling and analysis problems hampered the gathering of gas-phase data.

Finding DII FEK-9. Little evidence of soot formation was indicated when the GPCR™ unit was tested separately with PCP-spiked wood, HD mortars, M55 rocket firing tubes, and neat GB.

Finding DII FEK-10. The full-scale SCWO reactor design has not been tested and is different in size and in the flow rates of the feed streams from those used in the Demo II tests. The full-scale design treats hydrolysate at a rate per unit volume of reactor that is almost 10 times higher than that used during the Demo II tests. In addition, the ratio of the flow rates of all other streams to the flow rate of hydrolysate in the full-scale unit has decreased by approximately a factor of 10 from those used during the Demo II tests. These changes in hydrolysate processing per unit of reactor volume and the reduction of other feed streams relative to the hydrolysate may reduce the efficacy of the SCWO reactor and may be expected to exacerbate problems of corrosion and plugging.

Finding DII FEK-11. The experience of multiple shutdowns during Demo II testing of the TW-SCWO and the resulting thermal stresses and crack generation in the liner indicate a potential reliability issue, which must be significantly reduced or eliminated.

Recommendation DII FEK-1. Since the hydrolysate/total feed ratio and flow velocity used in Demo II testing are so different from those of the proposed design, the TW-SCWO reactor must be tested at a hydrolysate/total feed ratio and flow velocities close to the proposed design conditions.

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Recommendation DII FEK-2. Long-term testing of appropriately designed SCWO reactor liners under the new operating conditions for the proposed full-scale operation will be necessary to prove the reliability and effectiveness of the TW-SCWO unit.

Recommendation DII FEK-3. Long-term testing of the TW-SCWO should include feeds containing chlorine, phosphorus, and sulfur and be at residence times and flow velocities close to the proposed design conditions.

Recommendation DII FEK-4. The Army or the technology provider must develop analytical methods to determine the quantities of agent in the gas streams containing hydrogen.

Teledyne-Commodore Demonstration Tests

Finding DII TC 1. Demo II tests were delayed and could not be completed for the Teledyne-Commodore process because of incidents in which the immaturity of the process became apparent. For example, an exothermic reaction between ammonia vapor and M28 propellant led to an ignition incident. At another time, Composition B, dissolved in liquid ammonia, leaked through flanges into valves and piping that were intended to transfer the material from the ammonia fluid jet-cutting vessel to the SET™ reactor. These incidents revealed serious safety problems associated with the Teledyne-Commodore process.

SUPPLEMENTAL GENERAL FINDINGS

General Finding DII 1. The demonstration tests were not operated long enough to show reliability in long-term operation. The PMACWA's Demo II tests were required to be of the same duration as the Demo I tests. The technology providers had neither the time nor the resources for extensive systemization (preoperational testing) in Demo II. Consequently, these tests were simply proof-of-concept demonstrations that indicate whether or not a particular unit operation (with more development) might be applicable to the disposal of assembled chemical munitions.

General Finding DII 2. The AEA technology package is a very complex, immature chemical processing system. Several new unit operations required to address problems revealed in the Demo II tests will significantly increase the complexity of an integrated processing system and extend the time required for its development.

General Finding DII 3. The demonstrated components of the FW/EL/K technology package are ready to progress to the EDS phase. However, certain key units were not tested (or the results were inconclusive). Additional testing will be needed to verify the ability of the transpiring-wall technology to minimize corrosion; the testing should be carried out in parallel with development of an engineering design.

General Finding DII 4. Because of fire and safety problems, the basic process for the Teledyne-Commodore technology was not tested in Demo II. The Army decided against going forward because the Demo II goals could not be met in time. As a result, the committee had no technical basis on which to evaluate the process any further.

General Finding DII 5. As was true for Demo I, none of the unit operations tested in Demo II has been integrated into a complete system. The lack of integration is a major concern and a significant obstacle to full-scale implementation.

SUPPLEMENTAL GENERAL RECOMMENDATIONS

General Recommendation DII 1. Further development of the Teledyne-Commodore technology package for the destruction of assembled chemical weapons should not be pursued under the ACWA program.

General Recommendation DII 2. Before the AEA technology proceeds to the EDS phase, extensive testing should be performed on the SILVER II™ process, including all the new unit operations that are being proposed to address the shortcomings identified in Demo II results.

General Recommendation DII 3. For the FW/EL/K technology package, additional testing should be performed in the EDS phase to complete GPCR™ off-gas characterization and demonstrate long-term operation of the modified TW-SWCO unit.

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Division on Engineering and Physical Sciences
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Preface

The United States has been in the process of destroying its chemical munitions for well over a decade. Initially, the U.S. Army, guided by recommendations from the National Research Council (NRC), decided to use incineration as its destruction method at all sites. However, citizens in some states with stockpile storage sites oppose incineration on the grounds that the exact nature of the effluents escaping from the stacks cannot be determined. The Army has continued to pursue incineration at four of the eight storage sites in the continental United States where that process seemed appropriate. Nevertheless, influenced by growing public opposition to incineration and the 1996 NRC report *Review and Evaluation of Alternative Chemical Disposal Technologies*, the Army has also been developing technologies based on chemical hydrolysis for the remaining sites. These processes will be used to destroy the VX nerve agent stored at Newport, Indiana, and the mustard agent stored at Aberdeen, Maryland, both of which are stored only in bulk one-ton containers and not in assembled munitions.

In 1996, persuaded by public opposition in Lexington, Kentucky, and Pueblo, Colorado, Congress enacted Public Law 104-201, which instructed the U.S. Department of Defense (DoD) to "conduct an assessment of the chemical demilitarization program for destruction of assembled chemical munitions and of the alternative demilitarization technologies and processes (other than incineration) that could be used for the destruction of the lethal chemical agents that are associated with these munitions." In response, the Army established the program manager for the Assembled Chemical Weapons Assessment (PMACWA). In Public Law 104-208, the PMACWA was required to "identify and demonstrate not less than two alternatives to the baseline incineration process for the demilitarization of assembled chemical weapons." During the first phase of the Assembled Chemical Weapons Assessment (ACWA) program, seven technologies were evaluated. Three of them proceeded to demonstration testing (Demo I) and one was dropped completely. In August 1999, the PMACWA selected two of the Demo I technologies as candidates for the destruction of the assembled munitions weapons at Pueblo Chemical Depot. The two packages, General Atomics Total Solution (GATS) and Parsons/Honeywell (formerly Parsons-Allied Signal) water hydrolysis of explosives and agent technology (WHEAT), were advanced to the engineering design study phase of the ACWA program.

The PMACWA has involved the citizen stakeholders in every aspect of the program, including the procurement process. The Keystone Center, a nonprofit organization, was hired to facilitate public involvement through a process known as the Dialogue, which has become a model for public involvement in matters of public concern.[1]

The Congress mandated that the Army coordinate with the NRC during the ACWA program. In response, the NRC established the Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons (ACW I committee) in 1997 to oversee this program. The question before the committee was not whether incineration was an adequate technology for destroying assembled chemical weapons but whether other chemical processes acceptable to the stakeholders could be

[1]The U.S. Department of Energy and the National Aeronautics and Space Administration have both adopted this approach. For example, at the NASA Jet Propulsion Laboratory, the Dialogue process will be used in developing a Mars sample-return mission, which is scheduled for 2012.

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used. The second NRC committee (ACW II committee) was established in the spring of 2000 to evaluate the two engineering design studies for the destruction facilities at Pueblo, Colorado, and Richmond, Kentucky, and to evaluate the demonstration testing of the three technology packages that had not been selected for those sites or for previous demonstration testing.

Although the PMACWA had no intention of demonstrating these three technologies, Public Law 106-79 (2000) mandated that the PMACWA "conduct evaluations of [the] three additional alternative technologies under the ACWA program." Furthermore, the PMACWA was directed to "proceed under the same guidelines as contained in Public Law 104-208 and continue to use the Dialogue process and Citizens' Advisory Technical Team and their consultants." Accordingly, the PMACWA initiated a program commonly referred to as Demo II to demonstrate the three technologies (AEA SILVER II™, the Foster Wheeler/Eco Logic/Kvaerner integrated demilitarization process, and Teledyne-Commodore's solvated electron process) that had not been selected during the first phase. The ACW II committee was asked to determine if and how the Demo II results affected its commentary, findings, and recommendations and the steps that were suggested for implementation in the ACW I report. This report presents the committee's evaluation of the second set of demonstration tests.

I wish to gratefully acknowledge the hard work of members of the ACW II committee, all of whom served as volunteers and provided the expertise necessary to carry out this enormous task. They gave relentlessly and unselfishly of their time and effort throughout the study. Their areas of expertise included chemical processing, biological remediation, environmental regulations and permitting, energetic materials, and public acceptance. Committee members attended plenary meetings, visited the technology providers' headquarters and test sites, observed design-review sessions, and studied the extensive literature, including engineering charts and diagrams, provided by the technology providers.

On behalf of the committee, I would like to also express appreciation for the extensive support of the Army ACWA team and its interactions with stakeholders and the Dialogue, particularly the group's Citizens Advisory Technical Team, whose members attended all open meetings of the committee and shared information and views with it. The committee also appreciated the openness and cordiality of the representatives of the technology providers. They and the Army provided early drafts of their test reports and other documentation to facilitate the committee's evaluation.

A study such as this requires extensive logistic support; the committee is indebted to the NRC staff for their assistance. I would particularly like to acknowledge the close working relationship I had with the NRC study director, Patricia Paulette. We worked as a team in leading this study. We spoke on the phone daily and e-mailed each other incessantly. The efforts of William Campbell, who took extensive notes and provided real-time report corrections at all our meetings as well as suggestions on how to best organize the report, were invaluable to the committee and to me. Gwen Roby provided the logistic support that enabled us to concentrate on our task. I am also indebted to my colleagues in the Chemistry Department at the University of Southern California who willingly took over my teaching duties while I traveled on behalf of this study.

Robert A. Beaudet, *Chair*
Committee on Review and Evaluation
of Alternative Technologies for
Demilitarization of Assembled
Chemical Weapons: Phase II

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Royce Murray, University of North Carolina, appointed by the National Research Council. He was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Acronyms, Chemical Symbols, and Abbreviations

ACWA	Assembled Chemical Weapons Assessment (program)
ACW I	Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons
ACW II	Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: Phase II
AEA	AEA Technologies Corporation
Ag^{2+}	silver II ions
AgCl	silver chloride
a-HAX	solution containing potassium hydroxide and humic acid
BIF	boiler and industrial furnace
CATOX	catalytic oxidation
CEES	chloroethyl ethyl sulfide
CEM	continuous emission monitor
CO	carbon monoxide
CO_2	carbon dioxide
Composition B	an energetic material that contains (nominally) 59.5 percent RDX, 39.5 percent TNT, and 1.0 percent wax
CWC	Chemical Weapons Convention
DAAMS	depot area air monitoring system
Demo I	Demonstration I (demonstration testing of three technologies selected for the first phase of ACWA technology testing)
DMMP	dimethyl methylphosphonate
DoD	U.S. Department of Defense
DPE	demilitarization protective ensemble
DRE	destruction and removal efficiency
ECBC	Edgewood Chemical and Biological Center
EDP	engineering design package
EDS	engineering design study
EPA	Environmental Protection Agency

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FEK or FW/EL/K	Foster Wheeler/Eco Logic/Kvaerner
GATS	General Atomics Total Solution
GB	a nerve agent
GC/MS	gas chromatography/mass spectrometry
GPCR™	gas-phase chemical reduction
H_2	hydrogen
HD	distilled mustard agent
HF	hydrofluoric acid
HNO_3	nitric acid
HPLC	high-performance liquid chromatography
HRA	health risk assessment
ICI	Imperial Chemical Industries
IMPA	isopropyl methylphosphonic acid
IRS	impurities removal system
KOH	potassium hydroxide
LMIDS	Lockheed Martin Integrated Demilitarization System
MACT	maximum achievable control technology
MDM	multipurpose demilitarization machine
MPA	methylphosphonic acid
M28	energetic material used for propulsion of certain assembled chemical weapons
N_2	nitrogen
NO_x	nitrogen oxides
N_2O	nitrous oxide
NRC	National Research Council
O_2	oxygen
PA	picric acid
PCP	pentachlorophenol
PGB	product gas burner
PMACWA	program manager for the Assembled Chemical Weapons Assessment
PMD	projectile mortar demilitarization (machine)
POTW	publicly owned treatment works
ppm	parts per million
PTFE	polytetrafluoroethylene (Teflon)
QRA	quantitative risk assessment
RCRA	Resource Conservation and Recovery Act
RDX	cyclotrimethylenetrinitramine
RFP	request for proposals
SCWO	supercritical water oxidation

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SET™	solvated electron technology
SILVER II™	electrochemical oxidation using silver II ions in nitric acid
SO_x	sulfur oxides
SO_2	sulfur dioxide
SVOC	semivolatile organic compound
TBA	tributylamine
TC	Teledyne-Commodore
TCLP	toxicity characteristic leachate procedure
TNB	trinitrobenzene
TNBA	trinitrobenzoic acid
TNT	trinitrotoluene, an energetic material
TOC	total organic carbon
TRBP	thermal reduction batch processor
TW-SCWO	transpiring-wall supercritical water oxidation
VOC	volatile organic compound
VX	a nerve agent
WHEAT	water hydrolysis of explosives and agent technology
3X	At the 3X decontamination level, solids are decontaminated to the point that agent concentration in the headspace above the encapsulated solid does not exceed the health-based, eight-hour, time-weighted average limit for worker exposure. The level for mustard agent is 3.0 mg per cubic meter in air. Materials classified as 3X may be handled by qualified plant workers using appropriate procedures but are not releasable to the environment or for general public reuse. In specific cases in which approval has been granted, a 3X material may be shipped to an approved hazardous waste treatment facility for disposal in a landfill or for further treatment.
5X level	Treatment of solids to a 5X decontamination level is accomplished by holding a material at 1,000°F for 15 minutes. This treatment results in completely decontaminated material that can be released for general use or sold (e.g., as scrap metal) to the general public in accordance with applicable federal, state, and local regulations.
5X treatment unit	This unit is used to heat chemical solid waste materials to a level of decontamination where no residual contamination is detectable.

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